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Nanotechnology in Space

Matthew N. O. Sadiku*, Guddi K. Suman, Sarhan M. Musa

Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX 77446
Email: sadiku@ieee.org; guddikarna@gmail.com; smmusa@pvamu.edu

Abstract Nanotechnology may be regarded as the engineering of functional systems at the molecular scale. It is taken as the scale range 1 to 100 nm. Nanotechnology is quickly becoming more "science" and less "fiction." While the technology of the tiny may seem irrelevant for taking on the vast unknown of space, it holds the potential to revolutionize many aspects of space exploration. The paper highlights the applications of nanotechnology for space exploration.

Keywords nanotechnology, nanotechnology in space

1. Introduction

Nanotechnology is naturally broad including fields of science such as organic chemistry, molecular biology, semiconductor physics, energy storage, engineering, microfabrication, and molecular engineering. Nanotechnology may be able to create many new materials and devices with a vast range of applications, such as nanomedicine, nanoelectronics, biomaterials energy production, and consumer products. Areas such as nanoelectronics, nanomechanics, nanophotonics, and nanoionics have evolved during the last few decades to provide a basic foundation of nanotechnology. Some popular applications of nanotechnology are shown in Figure 1 [1].

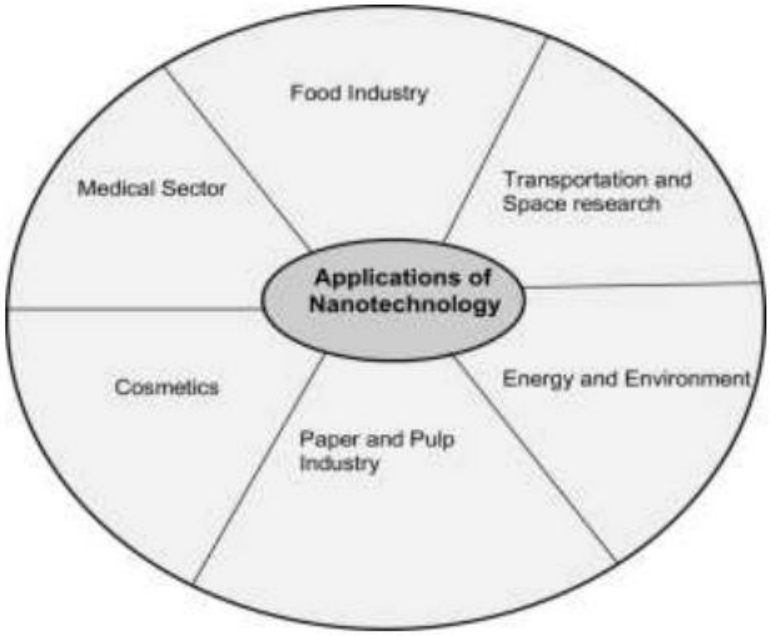

Figure 1: Different applications of nanotechnology [1]

For a long time, humans have been dreaming about space travel. Human dreams and imagination tend to give rise to new technology. Space exploration and nanotechnology were born out of such dreams. Although space travel and space exploration are exciting, space is fundamentally unfriendly environment for humans. Space exploration can take advantage of nanotechnology. It is expensive and risky and extremely inefficient. A nanotech solution would be much more efficient—such as exploring with nanobots before humans travel to the planets [2].

The harsh space environment and extreme costs of space missions place new demands on materials used in aerospace systems. The lightweight and high-strength properties of nanomaterials are currently being examined to support aerospace applications. Nanotechnology could contribute to improving the spacecraft themselves, while also protecting both astronauts and equipment.

Overview of Nanotechnology

Richard Feymann, the Nobel Prize-winning physicist, introduced the world to nanotechnology in 1959. The term "nanotechnology" was coined in 1974 by Norio Tanigutchi, a professor at Tokyo Science University. Nanotechnology involves the manipulation of atoms and molecules at the nanoscale so that materials have new unique properties. It is the science of small things—at the atomic level or nanoscale level [3]. Nanotechnology also includes domains like nanoscience, nanomaterials, nanomedicine, nanomeasurement, nanomanipulation, nanoelectronics, and nanorobotics.

Techniques are now available which make it possible to manipulate materials on the atomic or molecular scale to produce objects which are no more than a few nanometres in diameter. The processes used to make and manipulate such materials are known as *nanotechnology*, the materials or objects themselves are called *nanomaterials*, and the study and discovery of these materials is known as *nanoscience*.

Nanomaterials are basically chemical substances or materials that are manufactured and used at a very small scale. Nanoscale materials can be engineered from minerals and nearly any chemical substance. Engineered nanomaterials have been deliberately manufactured by humans to have certain required properties. Nanomaterials may also be produced incidentally as a byproduct of mechanical or industrial processes [4]. They can be classified in 0D, 1D, 2D and 3D nanomaterials. Nanomaterials such as Carbon nanotubes are 100 times stronger than steel but six times lighter!

Nanotechnology has the idea that the technology of the future will be built on atoms. It has impact on every area of science and technology. Nanotechnology involves imaging, measuring, modeling, and manipulating matter at the nano scale. At this level, the physical, chemical, and biological properties of materials fundamentally differ from the properties of individual atoms and molecules or bulk matter [5].

Nanotechnology covers a wide variety of disciplines like physics, chemistry, biology, biotechnology, information technology, engineering, and their potential applications.

Some of the sectors covered by nanotechnology are shown in Figure 2 [6]. Nanotechnology features two primary approaches, which are "bottom up" where materials or devices are self-assembled from molecular components, and "top down" where nanoscale objects are constructed by micro-scale and macro-scale devices.

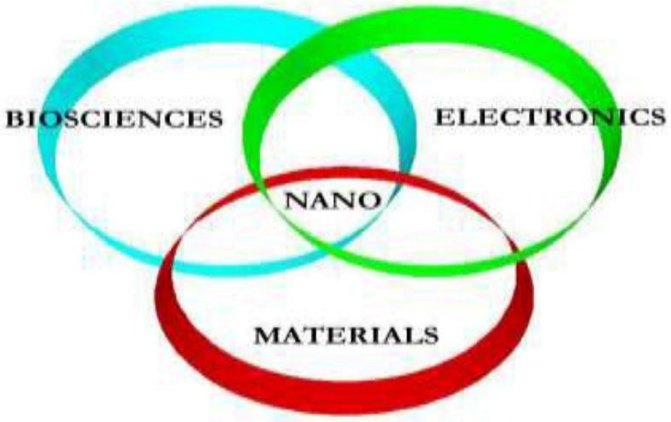

Figure 2: Scope of nanotechnology [6]

Applications

There are various ways nanotechnology could help space travel. Popular areas of applications of nanotech in space include space elevator, protecting satellites from energy weapons, propulsion systems, radiating shielding, anti-satellite weapon counter measure, space instrumentation, and bio-nano robot-laced spacesuits [7-11].

Radiation shielding: This is an area where nanotechnology plays an important role in human space flight. According to NASA, the risks of exposure to space radiation are the most significant factor restricting humans' capacity to participate in long-duration space missions. Advanced nanomaterials provide effective radiation shielding as well as energy storage.

Protecting satellites from energy weapons: Nanotechnology can be used to improve the design of satellites to mitigate the threats posed by ground-based directed energy weapons and high-powered microwaves.

Drug delivery: Novel means for drug delivery and nanoscale screening tools will help astronauts projecting to Mars and places beyond, whereas the space laboratory will promote progresses in nanotechnologies for diagnostic and therapeutic tools to assist patients here on earth.

Space elevator: This is another way to get into space. It involves a cable extending from the earth's surface into space with a center of mass at geosynchronous altitude. Such a structure requires an incredibly long cable (approximately 90,000 km) and would require being stronger than any cable found on earth. Carbon nanotubes (CNTs) are a promising candidate. A CNT cable could be tethered to an asteroid in orbit and an anchor station on earth. Many engineering challenges must be overcome before such an elevator could be established. A space elevator based on carbon nanotube cables is one of those ideas from 1950s-style futurism. A major obstacle to making a space elevator is finding a material for the cable that is strong enough to withstand a huge amount of tension. An example space elevator is shown in Figure 3 [12].

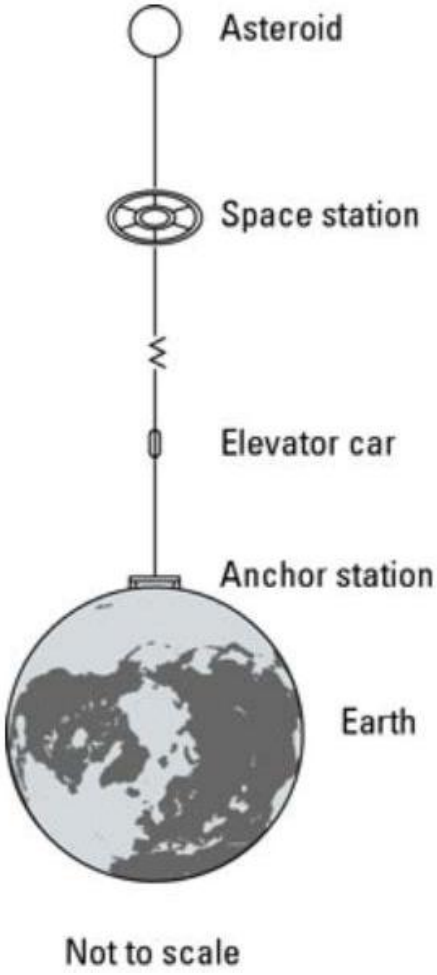

Figure 3: Space elevator [12]

Nanorobot swarm: Robots can perform well even in space exploration. Space robotic systems (such as robots in orbit, planetary rovers, or even satellites) are of great importance to space exploration and perform tasks hazardous or impossible for humans. However, space robotic systems can be very big in size. Nanobots can effectively cover more ground and explore at fast rates. They operate using some form of artificial intelligence (AI) that enables them to communicate and self-organize. Nanobot swarms could be effective in exploring the thick atmosphere of planets like Venus, or the stormy gaseous planets such as Jupiter and Saturn, by releasing nanobots or nanosensors into the atmosphere. Other planets can be explored with nanobots before humans travel to these planets. By nature, nanorobots are invisible to the naked eye. However, the idea of launching thousands of bots into space is easier said than done. An artist's conception of nanorobots is shown in Figure 4 [9].

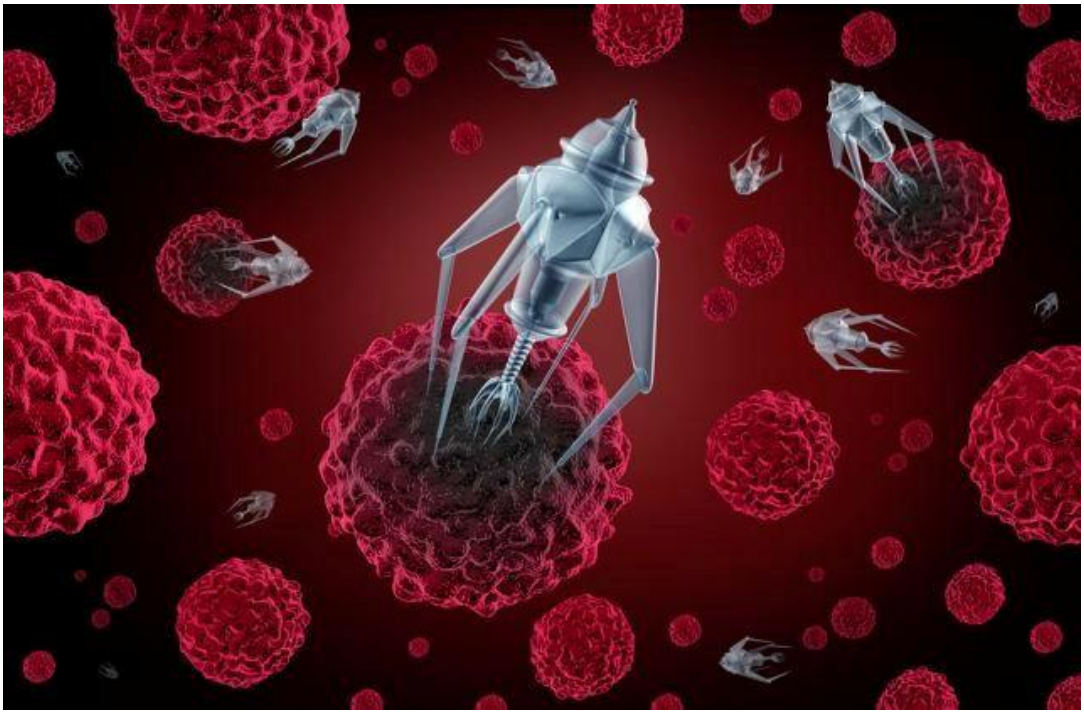

Figure 4: Artist's conception of nanorobots that can enter the human body [9]

Nanosatellites: The United States relies on space operations of satellites for its security.

Access to space today is widely expensive and available to only governments and a few corporations. Now nanosatellites and companies like SkyBox are transforming space access, making it affordable. Nanosatellites are tiny (as small as 10 cubic centimeters), cost less than a dollar 1 million to build and launch into space, and are more available to everyone. The satellites provide more practical applications for space programs such as monitoring, reduction, and removal of space debris. Space operations and the ability to deny another country's freedom of access to space are no longer possible. Nanosatellites provide inexpensive access for entertainment, education, convenience, and variety of other applications.

Some of these applications are still years away. There are nanotech applications that would monitor and repair the astronaut inside.

Benefits and Challenges

Right from the beginning of the space era, the expansion of new technologies most suitable for habitat and adaptation in space has equally helped life on earth. Nanotechnology could make spaceflight more realistic and practical. Spacecraft nanomaterials will play a critical role. Advancements in nanomaterials make lightweight solar sails and a cable for the space elevator possible. The cost reduction in space transportation can be achieved by reducing mass and volume of spacecrafts and payload. Nanotechnology holds great potential for pollution prevention and sustainability. It is capable of producing carbon-based material that is light in weight yet sufficient to resist the forces it would subjected to.

However, a rosy outlook by no means guarantees a problem-free outcome.

Nanotechnology raises many of the same issues as any new technology, including concerns about the toxicity and environmental impact of nanomaterials. Spacecraft materials are often viewed as high-tech. They must be reliable because the space environment is hostile. Cost is always a major consideration. However, if there is a justifiable technological advantage to using a new material, any increased cost is acceptable. Nanomaterials can provide this advantage. The space environment pushes nanomaterials "to the edge" of their performance. Achieving utter reliability is a challenge for nanomaterials [13]. Another area of concern is the effect that industrialscale manufacturing and use of nanomaterials would have on human health and the environment. With this in mind, some groups advocate that nanotechnology be regulated by governments.
These are some of the challenges to overcome before we see some of these ideas launching into orbit.

Conclusion

Today, research on nanoengineering and nanotechnology is booming, The integration of nanotechnology and space technology has boosted the space technology tremendously. Nanotechnology will play a major role in future space missions. Scientists and engineers currently debate the future implications of nanotechnology. Nanotech experts from industry, academia, and government are working together to apply nanotechnology and nanomaterials in the space industry. More information about nanotechnology in space can be found in the books in [8,14,15] and the related journals:

- *Nanotechnology*
- *Nanoscale.*
- *Journal of Nanoscience and Nanotechnology,*
- *Journal of Micro and Nano-Manufacturing*
- *Journal of Nanoengineering and Nanomanufacturing*
- *NASA Tech Briefs Magazine*

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About the Authors

Matthew N.O. Sadiku is a professor emeritus in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interest include computational electromagnetics and computer networks. He is a fellow of IEEE.

Guddi K. Suman is currently working towards a PhD in Electrical and Computer Engineering at Prairie View A&M University, Prairie View, TX. Her areas of research interest include space radiation effects on electronics, nanomaterials, characterization of nanomaterials and semiconductors, thin film nanofabrication, and nanosensors. She is a student member of IEEE.

Sarhan M. Musa is a professor in the Department of Electrical and Computer Engineering at Prairie View A&M University, Texas. He has been the director of Prairie View Networking Academy, Texas, since 2004. He is an LTD Sprint and Boeing Welliver Fellow. His areas of research interest include computational electromagnetics and computer networks.